Notes on the Biology of *Halictus (Halictus) farinosus* Smith (Hymenoptera: Halictidae)

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ABSTRACT

Describes the habitat, life history, foraging, social behavior, and nest architecture of the subsocial halictine bee *Halictus* (*Halictus*) *farinosus* Smith. The interplay of host-plant conditions with nest development and generations is discussed. Natural enemies and other associates are noted but not extensively treated.

KEYWORDS: halictine bees, *Halictus farinosus*, host plant conditions, nest development, soil-nesting bees.

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NOTES ON THE BIOLOGY OF *HALICTUS (HALICTUS) FARINOSUS* SMITH (HYMENOPTERA: HALICTIDAE)

By William P. Nye[1]

INTRODUCTION

Halictus Latreille is a genus of subsocial, soil-nesting, halictine bees. The subfamily is characterized by the strongly bent basal vein of the forewing and the linear, longitudinal pseudopygidium of the sixth tergum of the females. The genus *Halictus* has apical hair bands on the abdominal terga. *Halictus farinosus* Smith is nonmetallic (no blue or green coloring), 12 to 14 mm in length, and has apical bands of golden-yellow pubescence on the abdominal terga. *Halictus parallelus* Say is a closely related species with a more easterly distribution in North America. It is readily distinguished from *H. farinosus* by its yellowish wings with infumate (smoky colored) apices.

H. farinosus, as reported by Sandhouse (*1941*),[2] extends from New Mexico west to California and north to British Columbia and Montana. Sandhouse examined specimens from New Mexico, Colorado, Arizona, Utah, Idaho, Montana, Nevada, California, Washington, and British Columbia and found that the species exhibited practically no variation. *Halictus farinosus* replaces *H. parallelus* in the States or portions of States west of the Continental Divide. On July 21, 1965, G. E. Bohart and P. F. Torchio (personal communication) collected *H. parallelus* at Shoshoni, Fremont Co., Wyo., located barely east of the Continental Divide.

No special biological studies have been published on *Halictus (Halictus) farinosus* Smith, but G. E. Bohart (*1952*) published a diagram of a nest of *H. farinosus* and Stephen et al. (*1979*) commented briefly on its biology. Roberts (*1973*) provided biological data on several species of *Halictus*. Distributional records (with implied habitat information) and host plant and flight data are contained in several taxonomic papers by Ashmead (*1903*), Crawford (*1902*), Roberts (*1973*), Robertson (*1928*), and Vachal (*1904*).

Biological studies have been published on *H. (Halictus) ligatus* Say by Chandler (*1955*), Kirkton (*1968*), Litte (*1977*), and Michener and Bennett (*1977*). A brief note was published on *H. parallelus* Say by Hungerford and Williams (*1912*).

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[2] The year in italic, when it follows the author(s)' name, refers to Literature Cited, p. 26.

NESTING SITES

Halictus farinosus nests in dry mesic canyons in mountainous regions, on scattered grass and brush-covered slopes, or in open woodlands. The nests may be singly or gregariously situated, a result of site utilization rather than any benefits derived from such groupings.

My study area was located in Green Canyon, Cache Co., Utah, approximately 3,200 m northeast of the Utah State University campus in Logan. The following four Green Canyon sites were studied:

Site 1.--800 m east of the Cache National Forest (CNF) boundary line on an "island" about 1.5 m wide and 25 m long in the middle of the roadway and on both sides of the road.

Site 2.--Approximately 1,100 m up the canyon from the CNF boundary line on the north side of the road in an area about 10 by 22 m.

Site 3.--1,600 m up the canyon from the CNF boundary line on a narrow slope about 2 to 3 m wide and 30 m long between the road and the dry wash. The nest area sloped from 5° to 15° in a southerly direction (fig. 1).

Figure 1.--Nesting site 3 on a narrow grass-covered slope between the road and the dry wash. Green Canyon, Utah.

Site 4.--2,400 m up the canyon from the CNF boundary line on the eastern edge of the road and along the hard packed trails, an area of approximately 40 by 60 m.

SOILS CONDITIONS AND VEGETATIVE COVER

The soil at the four nesting sites was classified as Millville Silt Loam. The physical characteristics of the soil from the nesting sites in Green Canyon were analyzed as follows: fine to very fine sand, 37 percent; silt, 50 percent; clay, 13 percent; pH, 8.1. The humus content seemed to be low, except in the top 7 to 10 cm where plant roots were abundant. The soil, when dry, was light gray-brown to a depth of approximately 60 cm. In general, the soil was hard and quite rocky, except at site 2, which had very few rocks. When moist, the soil was darker in color, easier to manipulate, but also more likely to crumble and ruin cells in the nest dissection. The surface did not crack when dry, but when disturbed, formed a fine dust. During rains, the water was rapidly absorbed. The only large cavities in the soil were those made by bees, ants, tiger beetle larvae, and root decomposition. The bees seemed to prefer rather dry, compact, and well-drained soil along roadsides and trails sparsely covered with short vegetation.

During the study, most of the soil surface in the four nesting

sites was covered with sparse growth of crested wheatgrass (*Agropyron cristatum* (L.) Gaertn.), scattered gum plant (*Grindelia squarrosa* (Pursh) Dunal), and Gray's lomatium (*Lomatium grayi* (Coult. & Rose) Coult. & Rose). The edges of roads, trails, and trampled or partially denuded areas favored the establishment of nests. Since the vegetation was low and sparse, the nests received very little shading during the early part of the day. Many nests established in the spring were hidden by vegetation as the plants grew taller, partially shading the nest by midsummer.

SEASONAL ACTIVITY

1976

In 1976, the first overwintering females (queens) of *Halictus farinosus* emerged from hibernation on April 1st and continued emerging until early May. During this period, the bees visited *Lomatium grayi* for nectar and pollen, and each individual dug a separate (25 to 45 cm deep) main burrow. They remained in the completed burrows (25 to 45 cm deep) for a number of days without further activity. The first brood cells were constructed in late May and early June, 10 to 15 cm below the surface. In guarding the nest, the bee faced the nest entrance. She usually assumed the guard position in dim light about 10 to 15 mm below the entrance of the main burrow. From this position, she could effectively block the entrance with her body and repel any intruder, including the small *Leucophora* flies (fig. 2).

The first progeny (all females) appeared as adults in late June and early July and became active as workers in the parental nests. As workers, they enlarged the nest, constructed and provisioned cells, and fashioned pollen balls on which the queen laid eggs.

The marked overwintering queens were last seen flying on July 28, overlapping the flight period of the first female progeny by 2 to 3 weeks. The first female progeny flew for a shorter period than the overwintering queens (disappearing about August 12).

The second female progeny began flying early in August and were last seen flying and taking nectar from rabbit brush on September 15. These females were not seen to provision any cells but left the nesting area to void wastes, feed, mate, and hibernate. I observed several successful matings on flowers of rabbit brush.

The first male bees were seen flying in late July, and the last were seen flying and taking nectar from rabbit brush on September 25. Male pupae were found in all nests after the emergence of the first-generation females.

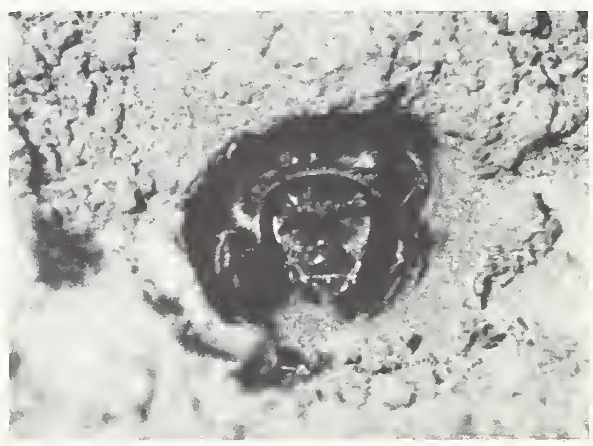

Figure 2.--*H. farinosus* guarding nest entrance.

1977

In 1977, the first observed overwintering female bee emerged from

hibernation on April 8, one week later than in 1976. Overwintering females continued to emerge until late May. The first progeny appeared on July 8 and became active as workers in the parental nests. The marked overwintering queens were last seen flying in early August, overlapping the flight period of the first female progeny by 2 to 3 weeks. The first female progeny constructed and provisioned cells and laid some eggs until August 20 (about 2 weeks later than in 1976). The second generation females began flying in mid-August and were last seen flying the taking nectar on September 26.

Males were first seen flying in early August and last seen flying and taking nectar on October 5.

The social structure became evident as the first female progeny emerged and became active as workers in the parental nest. The queen remained in the nest, acting as nest guard and primary egg layer; however, when the queen began to fail (or died), one of the workers took over as guard and primary egg layer. Since she had no access to males, all of her progeny were male.

NUMBER OF ACTIVE NESTS

The number of active nests was greatest during May when overwintering females were returning to the nesting sites and digging their main burrows. The number of active nests by month and year at site 1 was as follows:

Date	*1976*	*1977*
May 15	368	383
June 15	98	225
July 15	81	158
Aug. 15	62	93

The rapid decline in the number of active nests in June 1976, as compared with 1977, may have resulted from the capture of a large number of female bees for the establishment of a nesting population at the Greenville Experimental Farm in North Logan, Utah.

Some overwintering females died after digging their main burrow (fig. 3). Others died before their first brood emerged, and the progeny abandoned the nest after emerging. In general, the decrease in the number of active nests was similar at each nesting site.

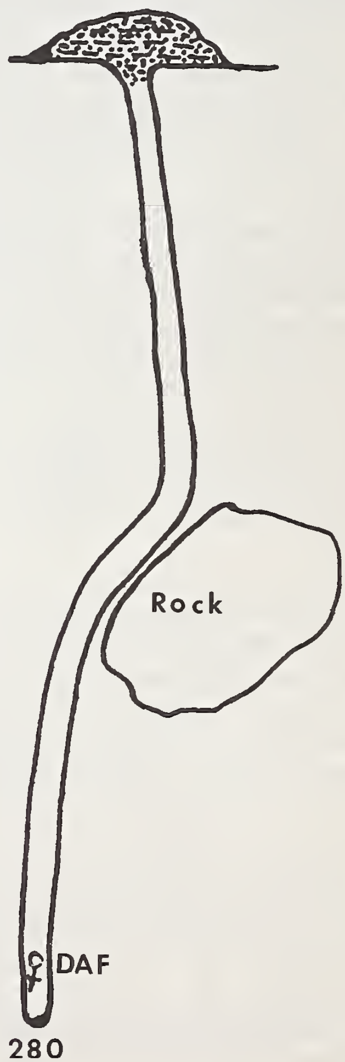

Figure 3.--Newly established spring nest with mainburrow well below cell level with tumulus closing of burrow. June 1, 1977.

FORAGING

Halictus farinosus is a polylectic species with a wide host range throughout the seasonal flight period. The species has been collected from many native and cultivated plants from April to October. Flowers visited were entomophilus annual, biennial, and perennial forbs with a lesser number of flowering shrubs and trees being frequented. Table 1 lists the activities of *H. farinosus* males and females on 43 plant species from 14 families on which they have been collected. Bohart and Nye (*1960*) found *H. farinosus* to be an important pollinator of carrots during the blooming period (fig. 4). Bohart et al. (*1979*) found *H. farinosus* to be an important pollinator of onions. *Melitus alba* Desr. and *Medicago sativa* L. (both legumes) were important sources of pollen and nectar (figs. 5 and 6).

Figure 4.--*H. farinosus* collecting pollen from carrot (*Daucus carota*).

Figure 5.--*H. farinosus* collecting pollen from white sweet clover (*Melilotus alba*).

Figure 6.--*H. farinosus* collecting pollen from alfalfa (*Medicago sativa*).

POLLEN IDENTIFICATION

The identification of pollens in pollen balls dissected from nests during the solitary and social nesting stages revealed that the bees collected pollen from two to seven different species of plants to provision one cell.

In 1976, when many species of plants were blooming, pollen balls examined contained pollen from an average of 3.18 different species of plants during the solitary nesting stage and 4.1 different species during the social nesting stage. Exam-

Table 1.--*Pollen and nectar gathering activity of* Halictus farinosus *males and females on plants in bloom in Green Canyon, Utah, from April to October, 1976-77*

[x, present during 10-day period; xx, present during 20-day period; xxx, present during 30-day period; +, visited uncommonly; ++, visited commonly; P, pollen; N, nectar]

Family	Species and common names	Apr.	May	June	July	Aug.	Sept.	Oct.	Other bees	*H. farinosus* foragers ♂	♀P	♀N
Asteraceae	*Achillea millefolium* L. Yarrow			x	xxx	xxx			++	+	++	+
	Agoseris glauca (Pursh) Raf. Mountain dandelion		xxx	xx					+		+	
	Aster canescens Pursh Hoary aster				xxx	xxx	xxx		++	+	+	
	Balsamorhiza sagittata (Pursh) Nuff Balsamroof		xxx	x							++	+
	Chrysothamnus nauseosus (Pall) Britton Rabbitbrush					xxx	xxx	x	++	++	++	++
	Circium foliosum (Hook) DC Elk thistle		xxx	xxx	xxx	xxx	x		++	+	+	
	Crepis acumminata Nutt. Long-leaved hawksbeard		xxx	xxx	xxx	xx			+	+	+	
	C. occidentalis Nutt. Western hawksbeard		xxx	xxx	xxx				+		+	
	Erigeron pumilus Nutt. Hairy fleabane daisy	x	xxx	xxx	xxx	xxx	xxx		++	+	+	
	Grindelia squarrosa (Pursh) Dunal. Gumplant				xxx	xxx	xxx		++	++	++	++
	Gutierrezia sarothrae (Pursh) Britton & Rusby Broom snakewood		xx	xxx	xxx	xxx	xxx	x	++	+	++	

	Helianthella uniflora											
	(Nutt.) Torr. & Gray		xx	xxx	xxx	xx			+		+	
	Little sunflower											
	Rudbeckia occidentalis Nutt.				xxx				+		+	
	Western coneflower											
	Senecio spp.				xxx	xx			+		+	
	Butterweed											
	Solidago canadensis L.				xxx	xxx	xxx	x	++	++	++	++
	Goldenrod											
	Taraxacum officinale Weber			xxx	xxx	xxx			++		+	
	Dandelion											
	Tragopogon dubius Scop.				xx	xxx			+	+	+	
	Salsify											
	Viguiera multiflora											
	(Nutt.) Blake				xxx	xxx	xxx		++	++	++	+
	Goldeneye											
	Wyethia ampleyicanlis											
	(Nutt.) Nutt.		xxx	xxx					++		++	
	Mule ears											
Umbelli-	*Lomatium dissectum*											
ferae	(Nutt.) Mathias/Constance	xxx	xxx	x					++		++	++
	Wild carrot											
	L. grayi (Coult. & Rose)											
	Coult. & Rose	xxx	xxx						++		++	++
	Gray's lomatium											
	Orogenia linearifolia											
	S. Wats.	xxx							+		+	
	Indian parsnip											
	Daucus carota L.											
	subsp. *carota*			x	xxx	xx			++	+	++	++
	Wild carrot											
Rosaceae	*Cercocarpus ledifolius* Nutt.			xx					++		+	+
	Curlleaf mahogany											
	Petrophytum caespitosum											
	(Nutt.) Rydb.				xxx	xxx	xxx		++	++	++	+
	Tufted rockmat											

Table 1.--*Pollen and nectar gathering activity of* **Halictus farinosus** *males and females on plants in bloom in Green Canyon, Utah, from April to October, 1976-77*--Continued

[x, present during 10-day period; xx, present during 20-day period; xxx, present during 30-day period; +, visited uncommonly; ++, visited commonly; P, pollen; N, nectar]

Family	Species and common names	Apr.	May	June	July	Aug.	Sept.	Oct.	Other bees	*H. farinosus* foragers ♂	♀P	♀N
Rosacea	*Prunus virginiana* L. Chokecherry		xxx	xx					++		+	+
	Malus pumila Mill.		xxx						++		+	+
Fabaceae	*Medicago sativa* L. Alfalfa			xxx	xxx	xxx			++		++	+
	Melilotus alba Desr. White sweetclover			xxx	xxx	xxx			++	+	++	+
	M. officinalis L. Yellow sweetclover			xxx	xxx	xxx			++	+	+	+
Liliaceae	*Allium cepa* L. Onion			xx	xxx				++		++	++
	A. acuminatum Hook Brandegee onion		xxx	xxx					+		+	
	Zigadenus paniculatus S. Wats. Deathcamas		xx						++		+	
Ranunculaceae	*Delphinium nelsoni* Greene Low larkspur		xxx						+		+	
	Ranunuculus ionis A. Nels. Sagebrush buttercup	xxx							+		+	
Aceraceae	*Acer grandidentatum* Nutt. Bigtooth maple		xxx						++		+	+
Convolvulaceae	*Convolvulus arvensis* L. Morning glory			xxx	xxx				+		+	
Cucurbitaceae	*Cucurbita pepo* L. Squash			xxx	xxx	xxx			++		+	

Hydrophyl-laceae	*Phacelia hastata* Dougl. Silver leaf phacelia			xxx	xxx		+	++	+
Menthaceae	*Marrubium vulgare* L. Horehound		xxx	xxx	xxx	++	+	++	++
Portulacea	*Claytonia lanceolata* Pursh Western spring beauty	xxx	xxx				+		+
Saxifray-aceae	*Ribes peteolare* Dougl. Western black current		xxx	xx			++		+
Violaceae	*Viola purpurea* Kellogg Yellow mountain violet	xxx	xxx				+		+

ples: On June 9, during the solitary nesting stage, one pollen ball examined contained pollen from *Balsamorhiza sagittata* (Pursh) Nutt., 20.33 percent; *Lomatium grayi*, 59.34 percent; *Phacelia hastata* Dougl., 20.33 percent; and one examined during the social nesting stage on July 9 contained pollen from *B. sagittata*, 28.43 percent; *Melilotus alba*, 3.93 percent; *P. hastata*, 55.88 percent; and *Taraxacum officinale* Weber, 11.76 percent.

In 1977, fewer species of plants bloomed than in 1976, and pollen balls examined contained pollen from an average of 2.95 different species of plants during the solitary nesting stage and 2.1 different species during the social nesting stage. Examples: On June 14, one pollen ball examined during the solitary nesting stage contained pollen from *Balsamorhiza sagittata*, 71.99 percent; and *Prunus virginiana* L., 28.01 percent; one examined during the social nesting stage on July 12 contained pollen from *B. sagittata*, 19.05 percent; and *P. virginiana*, 80.95 percent.

MARKINGS OF FORAGERS

The duration of individual foraging trips as well as the number of bees flying from marked nests was studied by marking the bees and clocking their arrivals and departures at the nest entrances. Most of the bees in the viewing area were marked on the dorsum of the thorax, using butyrate dope paint and small, numbered disks. The disks were cemented onto the dorsum of the thorax with stiff shellac. A 3-inch screen cone with a 2-dr vial inserted in the small end was placed over the nest entrance to bar exit of emerging bees and to prevent entrance by returning bees. Exiting bees trapped in the cones were transferred to a holder for marking and release. The returning bees were netted, transferred to the holder, marked, and released. The holder was a plastic tube 3 cm in diameter and 7 cm long with 3- by 4-mm mesh cloth netting stretched across one end and a sponge plastic-covered cork plunger to press the bee against the netting for marking. The bee was then marked through the netting. Most of the marked bees returned to the nest in 5 to 30 minutes. A few of the marked bees were never seen again and may have been injured during marking.

The overwintering females were marked with orange paint or disks, and the workers were marked with yellow paint. The plastic disks for marking honey bees were found to be a bit too large for *H. farinosus* and were used only in 1976. The dope paint and the small numbered paper disks (1.5 mm) were the most successful means of marking.

Before discontinuing the use of the plastic disks, I was successful in marking the overwintering females in six nests during the solitary nesting phase and all of the individuals in three nests during the social nesting phase.

FLIGHT ACTIVITY

The duration of foraging trips during the solitary nesting stage is illustrated in table 2 for data obtained during a 2-day period for 13 nests in 1977. The average duration per trip to collect a load of pollen was 131

Table 2.--*Flight activity of* H. farinosus *during solitary nesting from 13 nests in viewing area, Green Canyon, Utah, June 23-24, 1977*

Date	Nest	Exit time	Return time	Trip in minutes[1]	Other activity
June 23	1				Guarding, digging, and sweeping entrance clean.
	2	1510	1700	110	Pollen gathering.
	3	1555	1730	95	Do.
	4	1030	1405	155	Do.
		1615	1730	75	Do.
	5	1410	1545	95	Do.
	6				Do.
	7				Do.
	8				Guarding.
	9				Do.
	10				Do.
	11	1045	1345	180	Pollen gathering.
	12	1100	1455	235	Do.
	13	1005	1305	180	Do.
	1				Guarding and sweeping entrance clean.
	2				Guarding.
	3				Do.
	4				Do.
	5				Do.
	6	1000	1200	120	Pollen gathering.
		1335	1520	105	Do.
	7				No activity
	8				Do.
	9				Do.
	10				Do.
	11	1000	1145	105	Pollen gathering.
		1300	1315	15	No pollen gathering.
	12	1055	1450	235	Pollen gathering.
	13				No activity.

[1]Average time per trip was 131 min.

min with a range of 75 to 235 min per trip.

In 1976, the duration of foraging trips for a 2-day period during the social nesting stage is shown in table 3. The average duration per trip was 118 min with a range of 65 to 152 min per trip.

At the Greenville Experimental Farm, 1860 m west of nesting site 1,

Table 3.--*Flight of* Halictus farinosus *during social nesting stage at nest 11, site 3, Green Canyon, Utah, July 20-21, 1976*

Date	Bee No.	Exit time	Return time	Trip in minutes[1]	Activity
July 20	1	0920	1149	149	Pollen gathering.
	1	1210	1430	140	Do.
	3	1245	1350	65	Do.
	2	1245	1400	75	Do.
	1	1445	1715	150	Do.
	2	1620	1750	90	Do.
21	2	0920	1148	148	Do.
	2	1158	1430	152	Do.
	2	1447	1607	80	Do.

[1]Average time per trip was 118 minutes.

a marked bee was observed collecting pollen from onion umbels for 3-1/2 min, visiting 23 umbels before she disappeared from sight. During that time, she collected about one-fifth or less of a load of pollen. In Green Canyon, 2050 m up the canyon from nesting site 4, a marked bee was observed collecting pollen from goldeneye (*Viguiera multiflora* (Nutt.) Blake) for 3 min, visiting 41 flowers before she disappeared from sight (fig. 7). She collected about the same amount of pollen as did the one observed on onions. Based on these and other observations, a bee could collect a load of pollen in 15 to 18 min; however, several bees were observed grooming themselves, and resting on flowers and leaves, and collecting nectar to sustain themselves during the long foraging trips before returning to the nest.

Figure 7.--*H. farinosus* collecting pollen from goldeneye (*Viguiera multiflora*).

NEST ARCHITECTURE

The *Halictus farinosus* nest pattern with its vertical main burrow and short horizontal laterals, each subtending a single horizontal cell, is similar to that of most other halictines. The cell cap is composed of a series of concentric spiral rings of soil visible on the inside of the cell cap but smooth and flush with the main burrow wall.

The following description is based on

observations of nests built by overwintering queen bees in the Green Canyon.

Tumulus-Turret

The main burrow was started late in the afternoon and evening. As the bee excavated her main burrow, she pushed up a symmetrical tumulus about 6 to 8 cm in diameter and 2 to 3 cm high around the entrance. She backed up the burrow, pushing moist soil, but did not expose her abdomen by clearing or tamping at this time. She then constructed a curved turret under the tumulus that acted as a horizontal passage leading from the actual burrow entrance to the edge of the tumulus. The lateral tunnel and burrow was always left open. She excavated a trail in front of the tumulus and kept it swept clean (fig. 8). A similar tumulus-turret is formed by *Nomia triangulifera* Vachal, except that this species always plugs the entrance when it leaves or enters the nest.

The tumulus-turret is easily washed away by rain or blown away by the wind. By midseason or before, it is usually gone. Figure 9 shows the bee cleaning the nest entrance after rain had washed away the tumulus-turret. The entrance to the vertical main burrow is circular and about 9 mm in diameter.

Figure 8.--*H. farinosus* sweeping trail in front of nest entrance.

Figure 9.--*H. farinosus* cleaning nest entrance after rain washed away the tumulus-turret.

Main Burrow

The vertical main burrow excavated by the overwintering queen was about 10 or 11 mm in diameter, but it narrowed toward the entrance and extended in depth from 25 to 30 cm, well below the cell level of the solitary nesting stage. The development of the nest during the solitary nesting phase is illustrated in figure 10 *A-C*. The burrow wall was smoothed and had no apparent lining.

During the social nesting stage, the main burrow was extended by the workers to depths of 40 cm or more. The development of the nest during the social nesting phase is illustrated in figure 11 *A-D*.

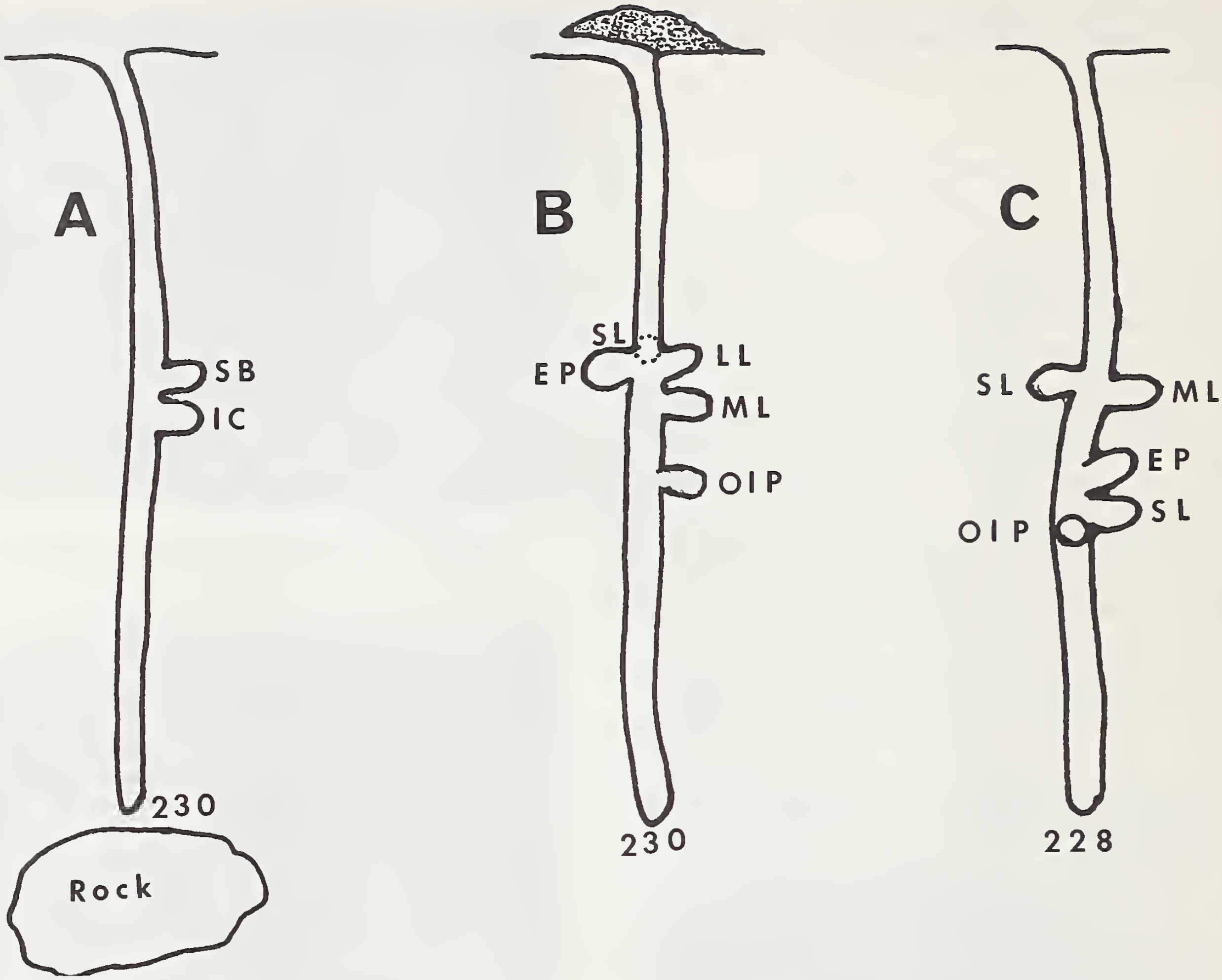

Figure 10 *A-C*.--Active nests: *A*, Two cells, one with small bombyliid larva feeding on host, and the second cell under construction and incomplete. June 16, 1977. *B*, Tumulus and horizontal entrance to main burrow still intact with five cells containing small larva, medium-sized larva, and large larva all feeding on pollen balls, pollen ball and egg, and open cell with incomplete provisions. June 16, 1977. *C*, Five cells, two with small larva, one with medium-sized larva, pollen ball and egg, and open cell with incomplete provisions. June 16, 1977.

Brood Cells

The first brood cells constructed by the queen bee during the solitary nesting stage were positioned 10 to 15 cm below the surface (fig. 12). Dissection of a nest during the solitary nesting stage is shown in figure 13. It shows a female pupa, two prepupae (the one on the left with a second stage bombyliid larva feeding on the host), and a second instar larva feeding on a pollen ball. Figure 14 shows an early third instar larva on a pollen ball in the cell.

Each cell was horizontal, oval in shape, arched at the maximum width, and flattened on the lower side. The entrance cap, which abutted the main burrow, was 3 to 5 mm thick. The cell

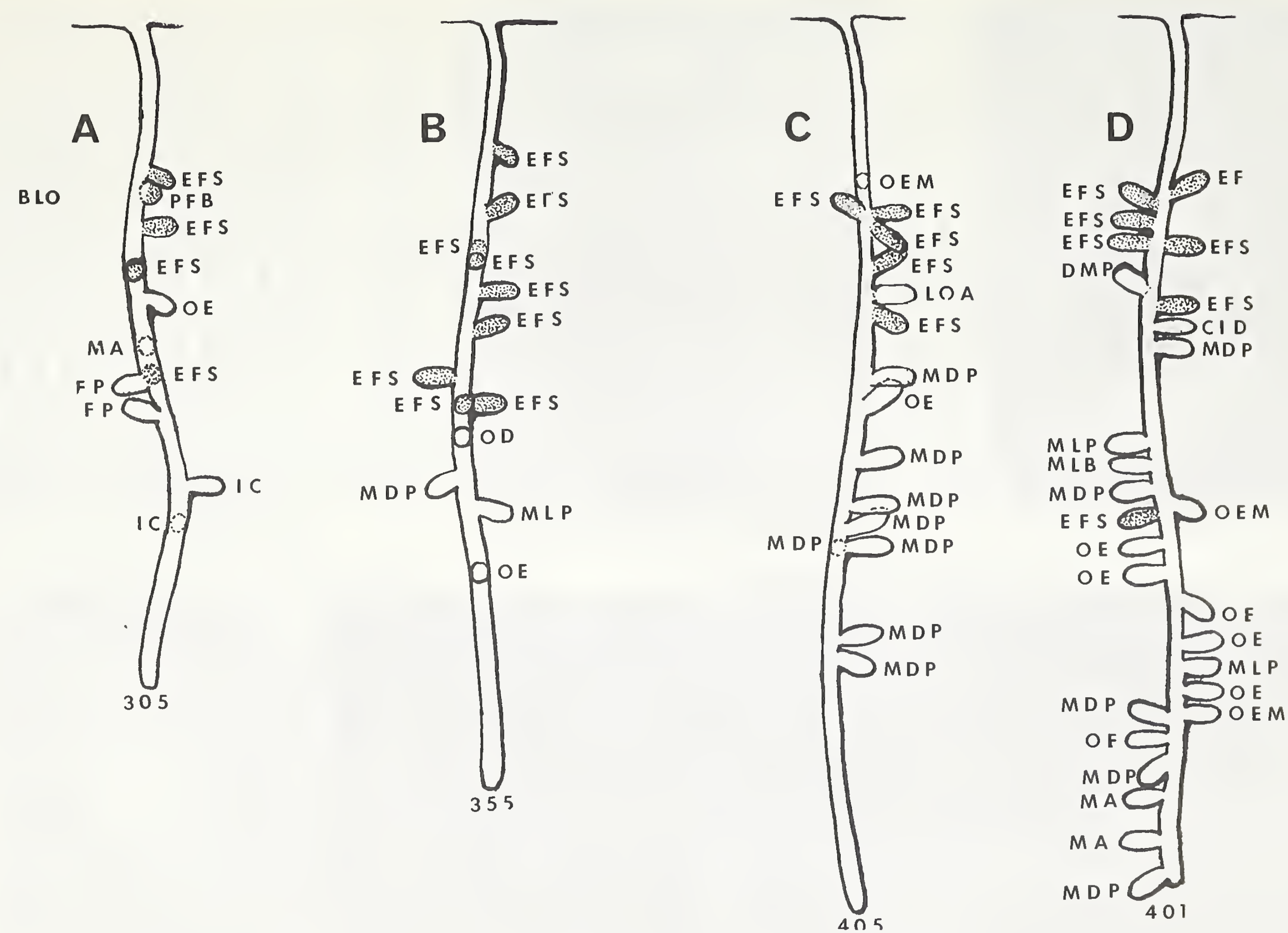

Figure 11 *A-D*.--Active social nests: *A*, Marked queen-guard and one daughter with pollen at entrance with no mature oocytes. Queen-guard had two mature oocytes. June 27, 1977. *B*, Marked queen-guard and one daughter newly emerged. Queen-guard with oosorption of two mature oocytes. July 14, 1977. *C*, Near end of season. Marked queen-guard dead in bottom of burrow. One daughter with immature oocytes and one newly emerged male, August 4, 1977. *D*, At end of nesting season. The marked queen-guarded was not found, assumed dead. Two daughters without oocytes. August 16, 1979.

Figure 12.--First brood cells located 10 to 15 cm below surface.

Figure 13.--A closeup of the first brood nest showing different stages of brood development--a female pupa, two prepupae (the one on the left with a second stage bombyliid larva feeding on host), and a second instar larva feeding on pollen ball.

itself was 16 to 18 mm long, and 9 to 10 mm wide at the widest point. The cell wall was very delicate and smooth with the apical 2/3 to 3/4 waxed and dark brown (fig. 15). The waxed lining was quite reflective when first dissected from the soil but became lighter

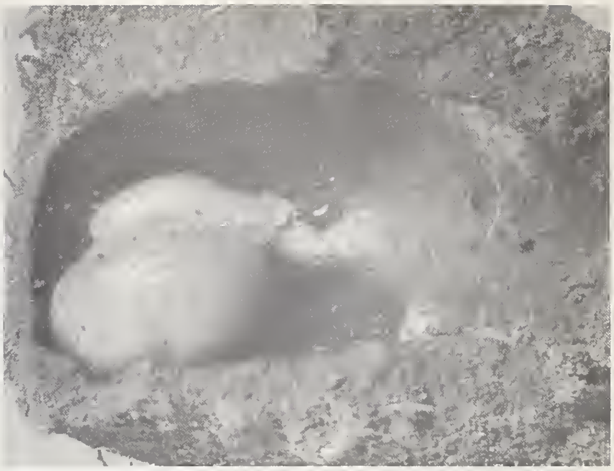

Figure 14.--Early third instar larva feeding on pollen ball.

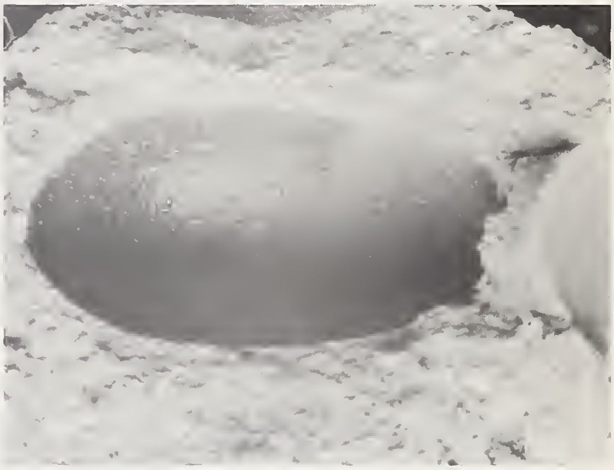

Figure 15.--Cell with apical 2/3 to 3/4 of cell waxed and entrance plug.

in color and almost invisible when exposed to the sun. The cells constructed by the workers during the social nesting stage were usually in a progressive sequence with each succeeding cell and group of cells at a deeper level.

The depth of cell placement appeared to be associated with moisture recession and heat penetration in midsummer. The more the moisture receded and heat penetrated into the soil, the deeper the bees constructed their brood cells.

Two to four cells were frequently constructed at the same or almost the same level and formed a cloverleaflike pattern (fig. 11 *C*). More commonly, the depth of succeeding cells was measurably different, sometimes directly or almost directly in line with each other. Gaps between cell groups were probably caused by decreased bee activity during inclement weather.

Provisions

The bees provisioned their cells with pollen collected from several plant species growing in the Green Canyon area. From five to eight loads of pollen were necessary to provision a cell. They fashioned the loads of rather dry pollen into a rough mass as each successive load was added (fig. 16). Next, they added nectar to the pollen and kneaded the rough mass into a slightly flattened sphere, somewhat flatter on top than on the bottom. The pollen balls were 5.5 to 6.5 mm in diameter and 4 to 5 mm high. The average weight of a pollen ball was 0.134 g with a range of 0.102 to 0.148 g. The males were smaller than the females and probably got the smaller provisions.

Figure 16.--Open cell with one or two loads of pollen fashioned into a rough mass as each successive load is added.

EGG-TO-ADULT DEVELOPMENT

The egg was laid in a shallow trough on the top of the slightly flattened doughlike pollen ball parallel to the long axis of the cell. The egg, when first laid, was milky in color and arched over the pollen ball. It was 4.2 to 4.5 mm long and about 1 to 1.2 mm in diameter. The posterior end of the egg was slightly embedded in the pollen ball while the anterior end rested on the pollen ball. The main body of the egg was arched above the pollen ball (fig. 17). The eggs of the first generation hatched in 3 to 5 days. As the embryo developed and appeared ready to hatch, the egg lost its arch and maintained full contact with the pollen ball. On the fourth day, the head and body segments were visible through the chorion (fig. 18). On the fifth day,

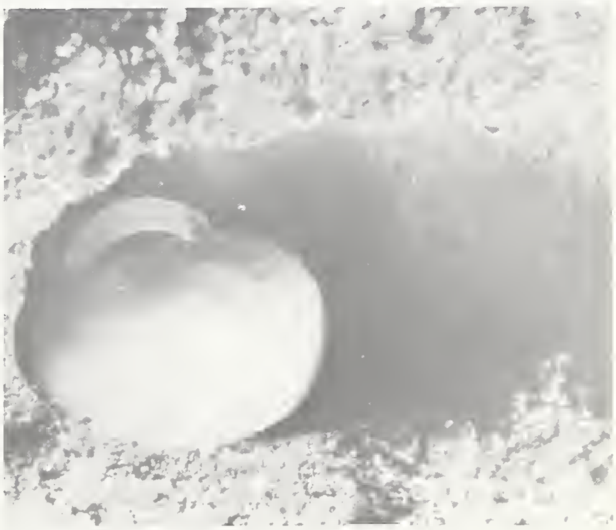

Figure 17.--Horizontal cell showing flattened lower side with pollen ball and egg.

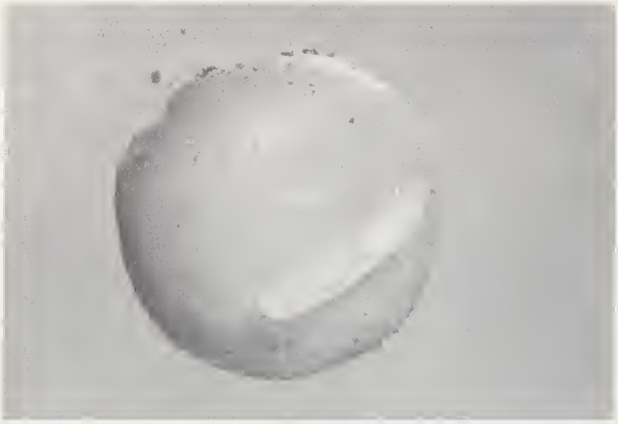

Figure 18.--The egg about ready to hatch is in full contact with pollen ball. The head and body segments of the embryo are visible through the chorion.

the first instar larva was free of the chorion and appeared to be feeding upon liquid on the surface of the pollen ball. The second instar larva consumed about one-third of the pollen ball, and pollen was visible through the translucent integument. The third instar larva moved more rapidly forward, pivoting from side to side as it fed, flattening the pollen ball on top and toward the anterior end. The third instar larva fed for 2 to 3 days, consuming the remaining two-thirds of the pollen ball (fig. 19).

The full-grown larva was smooth, slightly moist, curved into a C-shape, and lay on its side in the cell (fig. 20). The body wall was nearly opaque, and the gut contents were almost invisible. Defecation began at this stage and continued for 2 to 3 days (fig. 21). The larva deposited ropey strands of brownish-yellow feces upon the rear walls of the cell. These soon became brown and were flattened into a continuous smear by the pressure of the prepupa.

The prepupa was whiter, less shiny, and not as large as before defecation. It straightened out and had only a wide-angled bend between the thorax and abdomen (fig. 22). It was still capable of movement when disturbed. The prepupal stage lasted 2 to 3 days.

The pupal stage lasted 7 to 10 days, and in this stage the male was distinguishable from the female (fig. 23) by its smaller size, more slender form, and longer antennae.

Figure 19.--The third instar larva completes its feeding by moving forward and resting its dorsal side on the bottom of the cell while feeding upside down on the partially encircled pollen ball residue.

Figure 20.--Full-grown larva.

Figure 21.--Mature larva depositing feces in cell.

Figure 22.--Prepupa.

Rearing from egg to adult was difficult in the laboratory. The first and second instar larvae had a high mortality; the larvae often stopped feeding, assumed an unnatural appearance, and had difficulty in molting. Third instar larvae, prepupae, and pupae, however, were readily reared to adulthood at room temperature and humidity. The approximate length of the brood was determined from rearing records and data from nest dissections.

In general, pollen balls were larger in the second generation brood stage, and the developmental period was about one week shorter. The faster rate of development was probably due to warmer soil temperatures during the second generation brood stage.

The immature stages took approximately the following times to develop: egg, 3 to 5 days; first instar larva, 1 to 3 days; second instar, 1 to 2 days; third instar, 2 to 3 days; defecation, 2 to 3 days; prepupa, 2 to 3 days; and pupa, 7 to 10 days.

Figure 23.--Female pupa.

DORMANCY AND HIBERNATION

Mated females of *H. farinosus* left the nesting site to undergo dormancy. Most of all that survived late summer dormancy and subsequent hibernation returned to the original nesting site in the spring to establish their nests.

To determine whether any of the bees hibernated in the nesting sites, sites 3 and 4 were marked off into a series of eight plots 2 by 2 m. One-half of the plots were then covered with clear lumite screen. The screens were placed over the nesting sites in late winter before the bees emerged from hibernation and were removed on May 11 after emergence. There was no sign that any bees had emerged or dug

new burrows in the screen-covered plots. This confirms the findings of G. E. Bohart (personal communication) who erected a large field cage over the nesting site in the fall, removed the cage in the spring, and found that no bees had emerged or renested in the screened area.

Perhaps the bees seek some area that offers them the greatest amount of protection from the elements. Such an area might possibly be along the north face of the canyon floor where they would be least affected by temperature changes during the fall, winter, and early spring.

PREDATORS AND PARASITES

The robber fly (*Mallophorina guidliana* (Williston)) was the only predator observed attacking adult female *H. farinosus* on the wing. The fly killed the bee by inserting its sharp probosis through the thin membrane between the head and thorax and then extracting body fluids.

The cleptoparasitic bee (*Sphecodes arvensiformis* Cockerell) was seen flying over the nesting sites and entering burrows of *H. farinosus* as well as those of *H. ligatus* Say and *H. rubicundus* Christ. *Sphecodes* is known to destroy the host egg and replace it with her own (fig. 24).

The larva of the inquilinous bee flies *Bombylius major* L. and *B. albicapillus* Leow were observed as parasites on the larvae of *H. farinosus*. The adult fly hovered over the nest of the host bee and hurled eggs into its open burrow. The eggs soon hatched and the first instar larvae crawled or were carried into the brood cells. Figure 25 shows the first instar bombyliid larva examining the host egg. The bombyliid larva then waited until the bee larva reached the prepupal stage before attaching itself to the host and beginning to feed (fig. 13), consuming one (and sometimes two) bee larvae before migrating to its own overwintering cell (fig. 26). The adult usually emerged the following spring as evidenced by the presence of the pupa and pupal exuviae in the host nesting site (fig. 27 and 28).

Figure 24.--*Sphecodes arvensiformis* egg on host pollen ball.

Figure 25.--First instar larva of bombyliid on host egg.

Leucophora obtusa (Zetterstedt), an anthomyid fly, was a fairly conspicuous, gregarious predator-parasite around *H. farinosus* nests; however, only a few host cells containing im-

mature stages of the fly were found (fig. 29). The flies entered the host nest entrance and laid their eggs near the mouth of the burrow.

Figure 26.--Bombyliid prepupa in overwintering cell.

Figure 27.--Bombyliid pupa.

Figure 28.--Bombyliid pupal exuviae in host nesting site.

The first instar larvae attached themselves to hairs on the bee's body and were transported to the cell by the bee. The maggots spoiled the pollen, and the first instar bee larva died. Occasionally, the bee larva was mature enough (usually a second instar) to feed rapidly enough to starve the fly maggots (fig. 30).

Minute ants, probably of the genus *Tapinoma* sp., occasionally invaded the sealed cell of the host through the back of the cell and consumed the cell contents. They were too small to pose any threat to the guard bee and were never seen in the nest burrow.

An anoetid mite (*Histiogaster* sp.) was often seen on the bee larvae, pupae, and adults (fig. 31). In the

Figure 29.--*Leucophora obtusa* adult female watching host bee at nest entrance.

Figure 30.--Maggots of *Leucophora obtusa* on pollen ball with second instar host larva.

cells, a pyemotid mite (*Trochometridium tribulatum* Cross) was often found associated with mold at the bottom of the cell (fig. 32).

A fungus, *Ascophaera* (possibly *A. apis* (Maassen and Claussen)), was found growing in the fecal pellets in cells, but there was no evidence that the fungus harmed the bee larva in any way (fig. 32).

A meloid beetle (*Nemognatha lutea* LeConte) was found ovipositing on gumplant (*Grindelia squarrosa* (Pursh) Dunal.) where the bees apparently acquired the *N. lutea* triungulinids.

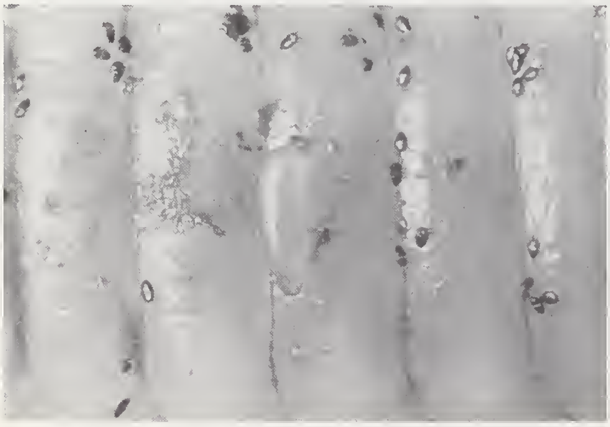

Figure 31.--Anoetid mites on prepupa of bee; also, egg of *Dasymutilla*.

Several *N. lutea* prepupae were found in the cells of *H. farinosus* (fig. 33).

I also collected *Meloe* sp. (Coleoptera: Meloidae) and *Dasymutilla* sp. (Hymenoptera: Mutillidae) in the

Figure 32.--Pyemotid mites on mold growing on the fecal pellets in the cell.

Figure 33.--*Nemognatha* puparium in host cell.

nesting sites of *H. farinosus* but did not find any immatures in nest dissection (fig. 34). In an earlier study with G. E. Bohart (unpublished communication), we found immatures of *Dasymutilla* (figs. 31 and 35) and larvae of the Rhipiphorid beetle, *Rhipiphorus*, feeding on prepupae of *H. farinosus* (fig. 36). We also found first-stage larvae of Strepsiptera, probably *Stylops* sp., just under the integument of the first instar host larva (fig. 37); however, Strepsiptera apparently did not develop on this host.

Figure 34.--*Dasymutilla* at host nest entrance.

Figure 36.--*Rhipiphorus* larva feeding on prepupa of host.

Figure 35.--First instar larva of *Dasymutilla* (arrow) feeding on prepupa of host.

Figure 37.--First instar larva of Strepsiptera under skin of first instar host larva.

DISCUSSION

Biological observations have been published on only about 6 to 10 percent of the species belonging to the family Halictidae occurring in America, north of Mexico. With few exceptions, such observations have been brief notes dealing with singular incidents such as nest construction, adult behavior, or flower visitation.

Halictine bees differ radically in their modes of life. Many species

are solitary forms in which each female is responsible for the construction and provisioning of her own nest. This behavior was observed in *Evylaeus galpinsiae* Cockerell by Bohart and Youssef (*1976*). Other species such as certain *Lasioglossum*, construct communal nests with a common entrance. Each nest is occupied by several females each of which constructs and maintains her own series of cells without the aid of other females. These nests continue to expand during the nesting season. Other species are more social and develop a worker caste as in some species of *Halictus*.

The biology of *Halictus farinosus* appears to differ in the following respects from the species of North American *Halictus* reported in the literature:

1. **Host range of flowering plants from which the bees have been recorded.** *H. farinosus* has been recorded from 43 species of plants from 14 families. Chandler (*1955*) reported 200 species from 41 families for *H. ligatus* Say; Dolphin (*1966*) recorded 165 species from 40 families for *Halictus* (Seladonia) *confusus* Smith. The larger hosts lists for *H. ligatus* and *H. confusus*, however, may result simply from more extensive collecting and searches through collected material.

2. **Place of hibernation.** *H. farinosus* left the nesting site to hibernate. Chandler (*1955*) reported that *H. ligatus* hibernated in old nests, and Dolphin (*1966*) reported that *H. confusus* constructed new burrows in the nesting site in which to hibernate.

3. **Emergence date of females from hibernation.** *H. farinosus* emerged on April 8; Chandler (*1955*) reported that *H. ligatus* emerged on May 3; and Dolphin (*1966*) reported that *H. confusus* emerged on April 19.

4. **The length of "resting" period after nest founding and prior to provisioning.** *H. farinosus* rested for 2 to 3 weeks, *H. ligatus* about 10 days to 2 weeks, while *H. confusus* rested for about 2 to 2½ weeks.

5. **Nest tunnels.** *H. farinosus* and *H. ligatus* constructed nearly vertical burrows, whereas *H. confusus* had a slanting entrance tunnel for 25 to 50 mm, adjoining a nearly vertical burrow.

6. **Tumulus.** The tumulus for *H. farinosus* was symmetrical with a horizontal entrance tunnel beneath the tumulus which was always left open. A similar tumulus turret is formed by *Nomia triangulifera* except that this species always plugs the entrance when it leaves or enters the nest. *H. ligatus* had a symmetrical tumulus around the nest entrance and plugged the entrance at night. *H. confusus* formed a semicircular mound some distance in front of the nest entrance and plugged the entrance at night.

7. **Appearance of first brood.** First brood of *H. farinosus* and *H. ligatus* appeared in late June, whereas the first brood of *H. confusus* appeared in mid-June.

8. **Nest architecture.** Main burrows constructed by the overwintering females of *H. farinosus* were the deepest, extending in depth from 250 to 300 mm, whereas the main burrows of *H. ligatus* and *H. confusus* ranged from 100 to 150 mm in depth.

9. **Length of foraging trips.** Foraging trips for *H. farinosus* varied in length from 15 to 235 min with an average of 131 min, and those of *H. ligatus* ranged from 20 to 45 min with an average of 30 min.

10. **Colony development.** *H. farinosus* produced small colonies. The first brood of two to five workers

(all females) produced an average of 17 cells; the second brood cycle produced both males and females. The females constituted the overwintering queens for the following year. Chandler (*1955*) reported three brood cycles for *H. ligatus* with the first brood cycle about the same size as that in *H. farinosus*. The nest population increased in a geometrical ratio as long as only workers were produced. The second brood in most nests were generally all females, further increasing the size of the nest. The third brood cycle contained both males and females. Once males and queens were produced, the colony diminished in size and strength since these bees contributed nothing to the economy of the colony. *H. confusus* produced colonies about the size of *H. ligatus*. Dolphin (*1966*) reported that males were present in all broods of *H. confusus*. Males were scarce in the first brood, became more common as the season progressed, and constituted 42 percent of the colony population. Males mated with females throughout the summer.

Further research is needed in the biology and behavior of *H. farinosus* to answer the following:

1. Do all the first progeny females of the queen become workers in the nest?

2. Does the queen lay any male eggs?

3. Where do the mated females overwinter?

4. Do all recently mated females leave the nest and go into dormancy?

SUMMARY

Halictus farinosus is a widely distributed halictine bee in the States or portions of States west of the Continental Divide. The life history of *H. farinosus* was studied during 1976 and 1977. This species is a social bee with a worker caste.

The topography of the nesting site is generally in dry mesic canyons, on flat or slightly sloping ground sparsely covered with vegetation. The nests may be singly or gregariously situated, a result of site utilization rather than any benefits derived from such groupings.

The species is one of a number of halictine bees that leave the nesting site entirely to hibernate. Most of them return to the nesting site in the spring of the following year. In 1977, the first queen emerged on April 8. When the bees emerged from hibernation, they visited *Lomatium grayi* for nectar and pollen to satisfy their own nutritional requirements. They began digging the main burrows in the nesting sites and remained in the burrows for a number of days without further activity. Bee activity, nest construction, and larval development were correlated with the sequence of seasonal events. During the early stage of nest construction, foraging and provisioning of cells, laying eggs, and guarding the nest were the same as for a solitary female of a nonsocial species.

The first female progeny appeared in late June and early July and became active as workers in the parental nests. As workers, they enlarged the nest, constructed and provisioned cells, and fashioned pollen balls on which the queen laid eggs.

The second progeny of bees emerged in mid-August and contained both males

and females. The second female progeny did not become active as workers in the parental nest but left the nesting area to void wastes, feed, mate, and hibernate.

The number of active nests declined with the advance of the season. The decline in number of nests was due partly to the death of the overwintering queen after digging their main burrows. Other queens died before the first brood emerged, and the bees abandoned the nest after emergence. The decline in active nests was similar at other nesting sites.

Although *H. farinosus* is polylectic, having been recorded from 43 species of plants, the principal flowers visited in the areas studied were *Balsamorhize sagittata*, *Lomatium grayi*, *Melitotus alba*, *Phacelia hastata*, *Prunus virginiana*, and *Taraxacum officinale*.

Nests constructed were vertical, with a single main shaft and a symmetrical tumulus-turret pattern with the entrance always left open and numerous very short horizontal laterals, each ending in a horizontal cell. The cell cap is composed of a series of concentric spiral rings of soil visible on the inside of the cell cap but smooth and flush with the main burrow wall. The horizontal cell constructed by the queen was 16 to 18 mm long, arched and 9 to 10 mm at the maximum width, flattened on the lower side, and the cap was 3 to 5 mm thick at the lateral entrance. The cell wall was very delicate and smoothed, and the apical 2/3 to 3/4 of the cell was waxed and dark brown. The cells constructed by the workers were similar and were in progressive sequence with each group constructed at a slightly deeper level.

About five to eight loads of rather dry pollen were necessary to provision a cell. Nectar was then added to the pollen and kneaded into a sphere, slightly flatter on top than on the bottom. The egg was laid in a groove on the top of the doughlike pollen ball, parallel to the long axis of the cell. When the egg was first laid, it was milky white in color and arched over the pollen ball. The development of the immature stages took approximately the following times to develop: Egg, 3 to 5 days; first instar larva, 1 to 3 days; second instar, 1 to 2 days; third instar, 2 to 3 days; defecation, 2 to 3 days; prepupa, 5 to 7 days; and pupa, 7 to 10 days.

Organisms found in the cells (other than *Halictus*) included a cleptoparasitic bee larva and several phorid fly larvae (feeding on pollen), microants, and mites (in cells and on pollen), and immatures of bee flies, mutillid, and a species of *Rhipophorus* beetles (feeding on host larvae).

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APPENDIX

Key to Symbols Used in Illustrations

AF Adult female in cell, recently emerged.

BL Bombyliid larva in overwintering cell.

CIP Cell closed with incomplete provisions.

DAF Dead adult female.

DMP Dead male pupa.

EFS Emerged and cell filled with soil, current season.

DL Diseased larva.

EP Egg on pollen ball.

FP Female pupa.

IC Incomplete cell. Construction is recent and incomplete.

LAF Live adult female.

LL Large larva.

LOA *Leucophora obtusa* adult.

LOL *Leucophora obtusa* larva.

MA Adult male in cell, recently emerged.

MDP Male, dark-colored pupa.

ML Medium-size larva.

MLB Medium-size bombyliid larva feeding on host.

MLP Male, light-colored pupa.

OD Open depleted cell; cell opened by ants and contents being eaten.

OE Adult emerged and cell open.

OEM Adult emerged, cell open; fungus hyphae on fecal deposit.

OIP Cell open with incomplete provisions.

PFB Partially filled cell containing remains of host fed upon by bombyliid larva.

SB Small bombyliid larva feeding on host.

SL Small larva.

Glossary

Anoetid Mites in the family Anoetidae are commonly referred to as anoetid mites.

Chorion Outer covering of egg.

Cleptoparasitic A thief, thievish, stealing the provisions from another.

Entomophilous Insect loving; applied to plants especially adapted for pollination by insects.

Halictine Bees in the subfamily Halictini (Halictidae) are commonly referred to as halictine bees.

Immatures Larval forms of insects.

Inquiline An associate. An insect that habitually lives in the nest of another species.

Integument The outer covering or cuticle of the insect body.

Meloid Blister-beetles of the family Meloidae (Coleoptera) are commonly referred to as meloid beetles.

Mesic Medium dry canyons.

Polylectic Collecting food (pollen and nectar) from a number of plant species.

Pyemotid Mites in the family Pyemotidae are commonly referred to as pyemotid mites.

Tumulus Mound of soil made in digging the main burrow.

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